CHAPTER 1

INTRODUCTION

The Efficient design and implementation of wireless sensor networks has become a hot area for researchers in the recent years, due to the vast potential of the sensor networks to enable the applications that connect the physical world to the virtual world. Potential applications for such large-scale wireless sensor networks exist in a variety of fields, including military operations medical monitoring, environmental monitoring, surveillance, home security and industrial machine monitoring. By networking large numbers of tiny sensor nodes, it is possible to obtain the data about physical phenomena that was difficult or impossible to obtain in more conventional ways. In the next coming years, as advances in micro-fabrication technology allow the cost of manufacturing sensor nodes to continue to drop, increasing deployments of wireless sensor networks are expected, with the networks eventually growing to large numbers of nodes.

1.1 Wireless Sensor network:

A review:

With the recent advancement in Micro Electro-Mechanical Systems (MEMS) technology, low power digital circuitry and RF designs, Wireless Sensor Networks (WSNs) are considered to be one of the potential emerging computing technologies, edging closer towards a widespread feasibility [5]. Several useful and varied applications of WSNs such as weather and climate monitoring, detection of chemical or biological agent threats, and healthcare monitoring require information gathering in harsh and inhospitable environments. Cheap and smart sensors networked through wireless communication with the Internet hold remarkable purposes for controlling and monitoring environment, homes, health care, military, and other strategic applications. These applications demand the use of various equipment including cameras, acoustic, Infrared and seismic tools and sensors measuring different physical parameters [7]. A network of the smart sensors can be deployed in a host of different environments, for example in the military scenarios, to detect various threats. Thus these networks can gather the intelligence in battlefields, track enemy lines, monitor potentially harmful chemical and the nuclear materials using neutron based detectors, and detect viruses, toxins using bio-sensor chips coated with antibodies to attract specific biological agents [10] [14].

In the Figure 1.1, it shows a typical cluster-based WSN architecture. The nodes detects the information and transmit it to the base station through an intermediate node called the cluster-head node. The cluster-head aggregates the data, compresses it and then transmits it to the base station. The base station serves as a gateway to send the data to the another network. The database connected to the base station provides the means to update and retrieve the data on demand.

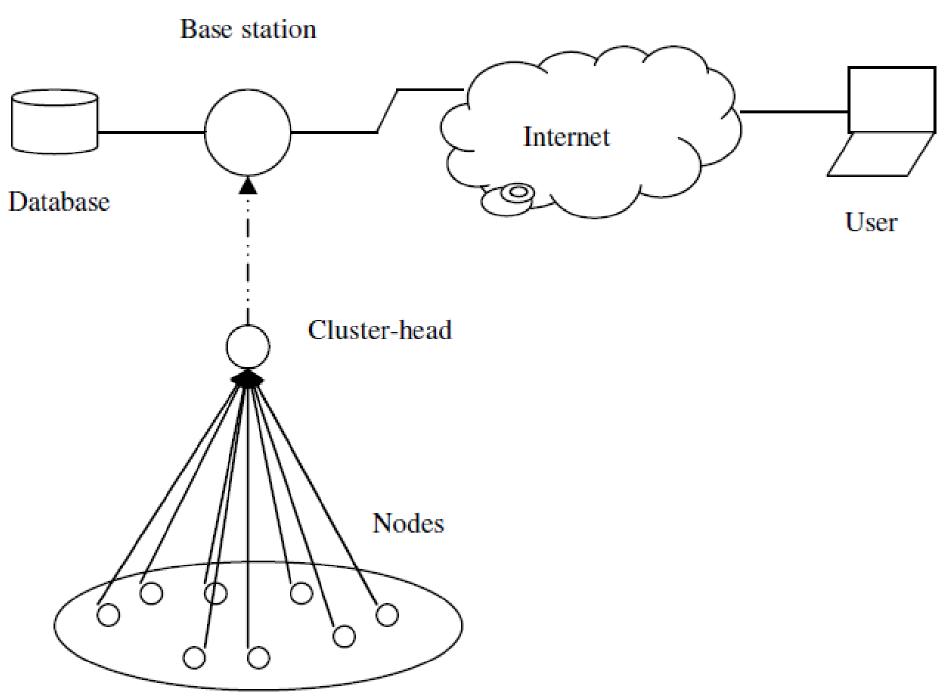

Figure 1.1: WSN architecture

It should be mentioned that the sensor networks do share some commonalities with the general ad hoc networks. Thus, the protocol design for the sensor networks must account for the properties of ad hoc networks, including the following.

• Lifetime constraints imposed by the limited energy supplies of the nodes in the network.

• Unreliable communication due to the wireless medium.

• Need for self-configuration, requiring a little or no human intervention.

However, several unique features exist in the WSNs that do not exist in the general ad hoc networks. These features present the new challenges and require the modification of designs for traditional ad hoc networks.

• While traditional ad hoc networks consist of the network sizes in the order of 10s, sensor networks are expected to scale to sizes of 1000s.

• The Sensor nodes are typically immobile, meaning that the mechanisms used in traditional ad hoc network protocols to deal with the mobility may be unnecessary and overweight.

• Since the nodes may be deployed in harsh environmental conditions, unexpected node failure may be common.

• Sensor nodes may be much smaller than the nodes in traditional ad hoc networks (e.g., PDAs, laptop computers), with smaller batteries leading to the shorter lifetimes, less computational power, and less memory.

• Additional services, such as location information, may be required in the wireless sensor networks.

• Communication is typically data-centric rather than address-centric, meaning that routed data may be aggregated/compressed/prioritized/dropped depending on the description of the data.

• Communication in sensor networks typically takes place in the form of very short packets, meaning that the relative overhead imposed at the different network layers becomes much more important.

• While nodes in traditional ad hoc networks compete for resources such as bandwidth, nodes in a sensor network can be expected to behave more cooperatively, since they are trying to accomplish a similar universal goal, typically related to maintaining an application-level quality of service (QoS), or fidelity.

1.2 Design Issues

In general, wireless ad-hoc networks most closely resemble the sensor network abstraction [7]. Although wireless ad-hoc networks are similar to WSNs, WSNs have several additional design issues and constraints:

- Firstly, sensor networks can contain the thousands of nodes and thus scalability is one of the major issues for this type of network.
- Secondly, sensor nodes in a WSN are severely constrained by the power, memory and computational capabilities which although serves as a factor in Wireless Ad-hoc Networks, is not that severe. Power efficiency is a critical constraint for WSNs. Once deployed, sensor nodes with finite power sources and limited recharging capabilities should be able to sustained the operation for months at a stretch.
- Thirdly, in the WSN only relevant data should be sent after compressing it as much as possible. The decision of condensing data and sending it to the base station should be made at node levels, i.e., in the sensor nodes and cluster-heads. The said issue is not that critical for Ad-hoc networks.
- Fourthly, in the case of Ad-hoc networks, routing in general takes place between any pair of the nodes whereas WSNs are meant for the purpose of sensing and gathering information and thus routing follows some distinct patterns [13] [8].

These patterns can be classified as given below -

(1) Many to one:The Sensor nodes in each cluster send the sensed data to the cluster-heads, which in turn aggregates the data and transmits it to the base station.

(2) One to many:The Base station or cluster-head multicasts (or broadcasts) different control and association signals to the sensor nodes.

(3) Local communication: In some topologies, the form of communication is desired for nodes to discover and co-ordinate with each other. Protocols like GAF (Geographical Adaptive Fidelity) [12] use this type of approach.

1.3 Sensors Types and Characteristics

There are different types of wireless smart sensors currently in use [10]. A more representative example is the sensor nodes of the smart dust project developed at UC Berkeley [5]. Figure 1.2 shows a general hardware platform description .

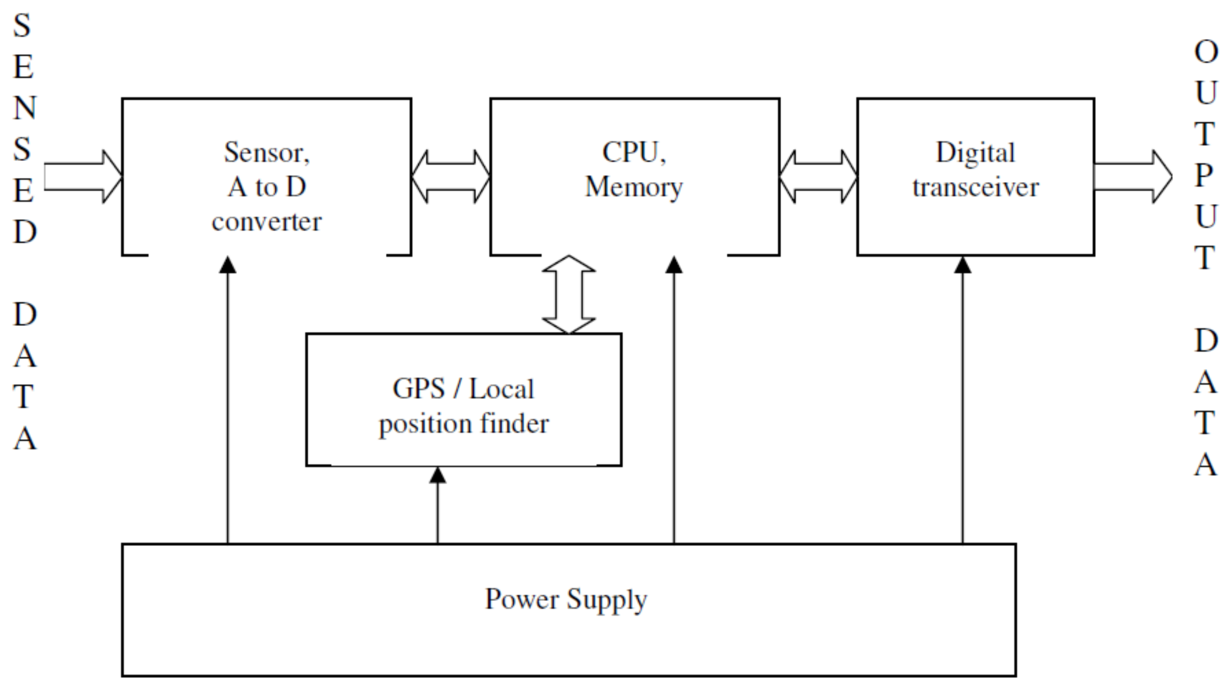

Figure 1.2: Sensor hardware platform

Different characteristics of sensor nodes includes the size, battery consumption, the power level, lifetime of the operation, movement characteristics (indicating whether nodes are stationary or mobile), position characteristics (indicating whether the nodes are embedded power Supply)

Designing suitable routing algorithms for different applications, fulfilling the different performance demands has been considered as an important issue in wireless sensor networks. In these context many routing algorithms have been proposed to improve the performance demands of various applications through the network layer of the wireless sensor networks protocol stack [3, 4], but most of them are based on single-path routing. In single-path routing approach basically source selects a single path which satisfies the performance demands of the application for transmitting the load towards the sink. Though the single path between the source and sink can be developed with minimum computation complexity and resource utilization, the other factors such as the limited capacity of single path reduces the available throughput [5]. Secondly, considering the unreliable wireless links single path routing is not flexible to link failures, degrading the network performance. Finding an alternate path after the primary path has disrupted to continue the data transmission will cause an extra overhead and increase delay in data delivery. Due to these factors single path routing cannot be considered effective technique to meet the performance demands of various applications.

To overcome these performance issues and to cope up with the limitations of the single path routing strategy, multi-path routing strategy also known as alternate path routing came into existence. As the name suggests there will be multiple paths established between the source and the destination through which the data can reach the destination [6]. Now how these links are used are totally based on the individual routing strategy. Some routing algorithms use the best path to send the data, keeping the other alternate paths as a backup and use it if the primary path fails, some use all the paths concurrently to send data and so on. In the past few years multi-path routing approach is extensively used for different network management purposes, such as providing a fault tolerant routing, improving transmission reliability, congestion control and Quality of Service(QoS) support in the wired and wireless networks, but the unique features of the wireless sensor networks and the characteristics of the short range radio communications introduce a new challenges that should be addressed in designing the multi-path routing protocols.

1.4 Routing in WSN:

Since transmission of data from the targeted source to the sink is the main task of the wireless sensor networks, the method used to do the data forwarding is an important issue which should be considered in developing these networks. Considering the unique features of low power wireless sensor networks, routing in WSN is much more challenging compared to traditional wireless networks such as ad-hoc networks [3, 4]. First, considering the high density of nodes, the routing protocols should route data over long distances, regardless of the network structure and size, in addition to the above requirement some of the active nodes may fail during the operations due to the environmental factors or energy depletion of sensor nodes or hardware faults, but these issues should not interrupt the normal operations of the network.

Moreover, as mentioned earlier the wireless sensor nodes are restricted in terms of power supply, processing capability and available bandwidth, routing and data forwarding should be performed with effective network resource utilization. Further, considering the performance demands of the wireless sensor networks are totally application dependent, routing algorithms should satisfy the QoS demands of the application for which the network is being deployed. For example, challenges in designing the routing algorithms for environment monitoring will be different from issues that should be considered for health care monitoring or target tracking. Based on the differences between wireless sensor networks and traditional wireless networks, various routing protocols were proposed over the past few years, to address the routing challenges introduced by the new features of the wireless sensor networks. The classification of protocols is based on in two different perspectives, network structure and protocol operation.

From network point of view, routing algorithms are classified as flat, hierarchical and location based routing protocols. Flat routing protocols are designed for network structure with homogeneous nodes meaning all nodes have the same transmission and processing capability. Directed Diffusion [7], Sensor Protocol for Information via Negotiation (SPIN) [8], Rumour Routing [9], Minimum Cost Forwarding Algorithm(MCFA) [10] , Energy Aware Routing(EAR) [11] can also be added in this category. In this group of protocols they demonstrate several advantages such as low topology maintenance overhead and the ability of multi-path discovery. Another group of protocols is the hierarchical routing protocols which were proposed to increase the scalability of the network and make the network energy efficient through node clustering. In this group of protocols all the sensor nodes are grouped into clusters and each cluster will have a cluster head which will be responsible for the collection of data from its cluster nodes, data processing and then forwarding the data towards the sink. Though this structure provides high network scalability, clustering operation but the cluster head replacement impose high signaling overhead to the network. Several routing algorithms such as Low-Energy Adaptive Clustering Hierarchy(LEACH), Threshold-Sensitive Energy-Efficient Sensor Network Protocol(TEEN) fall in this category [2].In two types of networks, i.e. homogeneous and heterogeneous networks, clustering can be done. Nodes with the same level of energy are called homogenous networks and nodes with different levels of energy are called heterogeneous networks. Low-Energy Adaptive Clustering Hierarchy (LEACH), Power Efficient Gathering in Sensor Information Systems (PEGASIS), Hybrid Energy-Efficient Distributed Clustering (HEED) are some algorithms designed for homogeneous WSN under consideration so that these protocols do not work effectively in heterogeneous scenarios because they are unable to treat nodes.

The next group of routing protocols utilize the exact location of the sensor nodes for the routing purposes. The geographic Location of the nodes can be obtained directly using Global Positioning System(GPS) devices or indirectly through exchanging some information regarding to the signal strengths received at each node. Since the localization requires special hardware support and also imposes significant computation overhead, this approach cannot be easily used in resource constrained wireless sensor networks. Geographic and Energy-Aware Routing(GEAR) and Geographic Adaptive Fidelity(GAF) can be referred as the geographic routing protocols.

1.5 Applications of Wireless Sensor Networks

WSNs have lots of application areas because of diversity of sensing devices used in the applications. These devices have ability to sense thermal, acoustic, infrared, pressure, humidity, temperature, noise etc. phenomenon in the environment. Every wireless sensor node characteristics depend on the requirements of applications. The categorization of application areas for WSNs is given below;

- Military applications,
- Environmental applications,
- Health applications,
- Smart home applications,
- Industrial applications

1.5.1 Military Applications

WSNs has important part of especially military command, control, communications, computing, intelligence, surveillance, reconnaissance and targeting systems. Easy of deployment, low-cost and disposable characteristics of sensor nodes make them very important for variety of military applications such as:

- Monitoring friendly forces, equipment and ammunition,

- Reconnaissance of opposing forces and terrain,
- Targeting,
- Battle damage assessment,
- Nuclear, biological, and chemical attack detection and reconnaissance

1.5.2 Environmental Applications

WSNs are also convenient to environmental applications such as monitoring animal movements, flood detection, forest fire detection, air pollution monitoring etc. due to the characteristic of deployment into inaccessible areas. Some environmental applications such as forest fire detection, solar cell equipped sensor nodes are used in order to provide network longevity.

1.5.3 Home Applications

The sensor nodes are used to control home appliances such as refrigerators, microwave ovens, vacuum cleaners, furniture etc. Sensor nodes which are embedded on these appliances have connection to the Internet. Thus end user can control these appliances remotely over Internet connection.

1.5.4 Industrial Applications

Monitoring and control of industrial equipment, factory process control and industrial automation, monitoring material fatigue, monitoring product quality are some of the application areas in the industry.

1.6 OBJECTIVE

A study of the impact of heterogeneity in terms of node energy is undergone in this research work. It is assumed that a percentage of the node population is equipped with more energy than the rest of the nodes in the same network—this is the case of heterogeneous sensor networks. This research is motivated by the fact that there are a lot of applications that would highly benefit from understanding the impact of such heterogeneity. These nodes will be equipped with more energy than the nodes that are already in use, which creates heterogeneity in terms of node energy. One of these applications could be the re-energization of sensor networks. As the lifetime of sensor networks is limited there is a need to re-energize the sensor network by adding more nodes. The energy efficiency as achieved in the DEEC as proposed in DEEC is one such protocol which takes the heterogeneity factor into consideration and improves the performance of the sensor nodes to a considerable extent. This is attributed to better problem solving capabilities of these algorithms in a complex mathematical model, involving a multitude of factors as is the case in heterogeneous network environment. Thus, it is believed that the performance of DEEC can be better improved.

1.7 Motivation:

Clustering is a technique in which network energy consumption[1] is well managed by minimizing the transmission range of the sensors. In this modus operandi, CH manages the group communication with the BS. Sensor nodes no longer transmit data directly to the BS instead CHs receive the whole group messages, aggregates and forwards to the BS.

All nodes in cluster transmit their data to corresponding CH. The CH issues a Time Division Multiple Access (TDMA) schedule for its member nodes to avoid collision. Each member node transmits its data to CH only in defined allocated time slot therefore, sensor nodes turn off their transceivers otherwise. TDMA scheduling encourages saving energy of sensor nodes and these nodes stay alive for longer period. As a rule, each member node transmits its data to nearby CH therefore; sensor nodes require minimum energy for data transmission. CHs perform computation on collected data and filter out the redundant bits, it reduces the amount of data that has to forward to the BS. Consequently, transmission energy of sensors reduce to significant amount.

The thesis is further organized as: Chapter 1 gives the Introduction and, Chapter 2 gives a detailed overview of the Wireless Sensor Networks and its various terminologies, Chapter 3 gives the detailed description of the System Architecture used in Implementation, Chapter 4 shows the implementation details and the results of simulation and Chapter 5 contains the conclusion and Future Work.

Chapter 2

Wireless Sensor Networks

2.1 Characteristics of Wireless Sensor Networks:

The WSNs have some different characteristics in comparison to other type of wireless networks that affects the network performance. These characteristics such as node density makealgorithms and protocols unique for WSNs. For instance, the number of sensor nodes in WSNs can be extremely higher than ad hoc networks and nodes are densely deployed. Node deployment, node capabilities, node density, energy constraints are all specific features of WSNs that affect network design and performance. Besides the node deaths occur frequently due to the battery depletion or a failure and this leads to topology changes.

2.2. Density and Node Deployment

The Node deployment can be either deterministic or self-organizing, which depend on the application. In deterministic method, nodes are placed on pre-determined locations and data routing is executed over pre-determined paths. It's also available to add some extra sensor nodes after the initial deployment in order to recover or support the network. On the other hand, in self-organizing WSNs, nodes are scattered randomly over the application area to form a network in an ad hoc manner.

2.2.1. Network Topologies

The IEEE 802.15.4 standard supports two types of the topologies as shown in Figure 2.1. In star topology, there must be at least one FFD as PAN coordinator to control devices in its respective PAN. The coordinator node is responsible for the controlling the PAN and communicating to the other PAN coordinators. In peer-to-peer topology there must be at least one PAN coordinator and nodes have to be in the communication ranges of one another to establish a link. In such a network every node acts as a router and supports multi-hop routing.This kind of topology is used in the mesh networks whichhave complex topology.

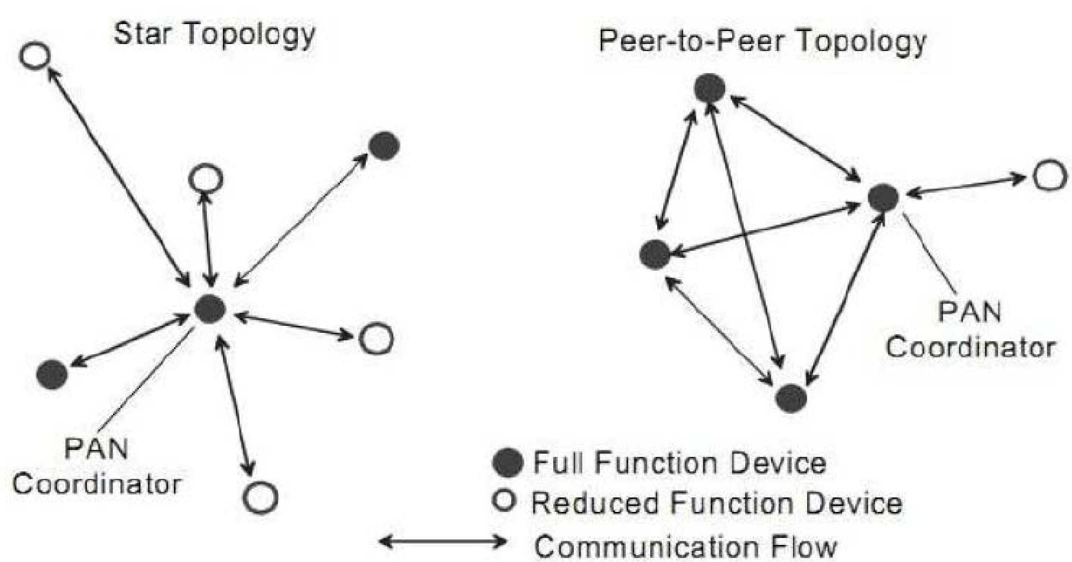

Figure 2.1 Star and peer-to-peer topologies and devices

2.2.2. Power Consumptions

A sensor node is a micro-electronic device having limited battery capacity. Network lifetime depends on battery lifetime of the sensor node, because it’s impractical to replace batteries of nodes that dispersed over inaccessible application areas. For instance, a Telos mote which has integrated CC2420 NIC is powered by two AA batteries (2.1 - 3.6V DC). Thus, the energy-efficient power management is highly critical for sensor networks.

Dynamic power management capability is an important requirement for the designing a sensor node. Thus, an event driven power consumption will extend sensor node lifetime. The Sensor nodes have different level of power consumptions for their states such as idle, sleep, receive, transmit etc. When we look at the TI CC2420 NIC datasheet, receive and transmit currents are extremely higher than idle current and sleep current (Table 1). IEEE 802.15.4 compliant devices have sleep modes and spend most of its time with sleeping, unless they receive or transmit a packet.

State	Value	Unit
Voltage Regulator Off	0.02	µA
Power Down	20	µA
Idle	426	µA
Receive	18.8	mA
Transmit	8.5 – 17.4	mA

Table 2.1 Power Consumption of TI CC2420 NIC

2.2.3. Heterogeneous Elements

The IEEE 802.15.4 defines two different types of the device with different capabilities. The FFD nodes have ability to act as PAN coordinator as a router and communicate with other coordinators or a simple devices, on the other hand RFD nodes have very simple task as communicating and sensing with a coordinator as shown in Figure 2.1.

In addition to mobility, these nodes are embedded on vehicles such as UAVs, buses or robots and do not suffer from the energy constraints. Compared to sensor nodes, these mobile nodes have rich system resources.

2.3. Application Areas of WSNs

The WSNs have lots of application areas because of the diversity of sensing devices used in the applications. These devices have the ability to sense and detectthe thermal, acoustic, infrared, humidity, temperature, pressure, noise etc. phenomenon in the environment.
Every wireless sensor node characteristics depend on the requirements of applications. The categorization of application areas for WSNs is given below;

- Military applications.
- Environmental applications.
- Health applications.
- Smart home applications.
- Industrial applications.

The application space of WSNs shows that node density, network scale and sensor types change in large scale interval depending on the type of application.Large-scale application areas sometimes require thousands of sensor nodes, but in some applications such as smart home devices, a few sensor nodes can be sufficient.

2.3.1 Military Application

The WSN can be used in various fields of military. Its self-configuration, unattended operation, fault tolerance make it very useful for military application.

(i). **Battlefield Surveillance**: Critical terrains, approach routes, paths can be coveredwith the sensor networks and by using its data activities of the opposing forces can be examined. As the operations progress and new plans are prepared, new sensor networks can be deployed for the battlefield surveillance.

(ii). **Monitoring Friendly Force Equipment and Ammunition**: The Commanders canmonitor the latest condition of its own force by using the WSNs. Each vehicle, equipmentand ammunitions are attached with a sensor which sends the current status to the sinknode from which the commander can monitor the situation.

(iii). **Nuclear Biological and Chemical Attack Detection**: The WSN can be deployed infriendly region and it can generate an alarm when it detects any Nuclear Biological andChemical Attack and it decrease the casualties at a large degree.

2.3.2. Environmental Applications

The WSNs are also convenient to environmental applications such as monitoring animal movements, flood detection, forest fire detection, air pollution monitoring etc. due to the characteristic of deployment into the inaccessible areas. Some environmental applications such as forest fire detection, solar cell equipped sensor nodes are used in order to provide network longevity.

Environmental application of WSN include tracking the movements of birds, small animals, and insects; monitoring environmental conditions that affect crops , macro instruments for large-scale Earth monitoring and planetary exploration, chemical/ biological detection, precision agriculture, biological, Earth, and environmental monitoringin marine, soil, and atmospheric contexts, meteorological or geophysical research, bio-complexity mapping of the environment and pollution study etc.

(i) Bio Complexity Mapping of Environment: A bio-complexity mapping of theenvironment integrate information across temporal and spatial scales. Although satelliteand airborne sensors can observe large bio-diversity (e.g., spatial complexity of dominantplant species) but they cannot be able observe small size bio-diversity, which makes upmost of the bio-diversity in an ecosystem. So there is a need for ground level deploymentof wireless sensor nodes to observe the bio complexity.

(ii)Precision Agriculture: The WSN has the ability to monitor pesticides level etc.

2.3.3 Home Applications

The sensor nodes are used to control various home appliances such as refrigerators,vacuum cleaners, microwave ovens, furniture etc. Sensor nodes which are embedded on these appliances have connection to the Internet. Thus end user can control these appliances remotely over Internet connection.

2.3.4 Industrial Applications

The Monitoring and control of industrial equipment, factory process control and industrial automation, monitoring material fatigue, monitoring product quality are some of the application areas in the industry.

2.4 Radio Model

According to the radio energy dissipation model illustrated in figure and in order to achieve an acceptable Signal-to-Noise Ratio (SNR) in transmitting an L-bit message over a distance d, the energy expended by the radio is given by:

$$E_{tx}(L,d) = \begin{cases} LE_{elec} + LE_{fs}d^2 & \text{if } d < do \\ LE_{elec} + LE_{mp}d^4 & \text{if } d > do \end{cases} \quad (2.1)$$

where E_{elec} is the energy dissipated per bit to run the transmitter(E_{TX}) or the receiver circuit(E_{RX}). The Eelec depends on many factors such as the digital coding, the modulation, the filtering, and the spreading of the signal. E_{fs} and E_{mp} depend on the transmitter amplifier model used, and d is the distance between the sender and the receiver. For the experiments described here, both the free space (d^2 power loss) and the multi path fading (d^4 power loss) channel models were used, depending on the distance between the transmitter and the receiver. If the distance is less than a threshold, the free space (f_s) model is used; otherwise, the multi path (mp) model is used. we have fixed the value of d0.

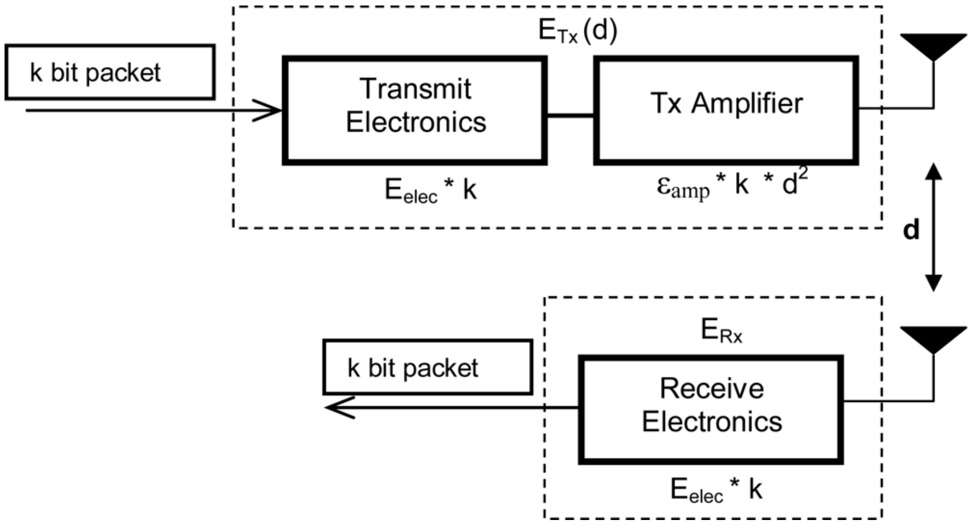

Figure 2.2: Network Model

The various equations for estimating average energy of networks and the cluster head selection algorithm which is based on residual energy where:
The average energy of rth round is set as follows:

$$E(t)=1/(N)E_{total}(1-r/R) \quad (2.2)$$

where R denote the total rounds of the network lifetime and is defined as:

$$R=E_{total}/E_{round} \quad (2.3)$$

E_{round} is the total energy dissipated in the network during a round, is equal to:

$$E_{round} = L(2NE_{elec} + NE_{DA} +kE_{mp}d^{4}_{toBS}+NEfsd^{2}_{toCH}) \quad (2.4)$$

where k is the number of clusters, E_{DA} is the data aggregation cost expended in the cluster heads, d_{toBS} is the average distance between the cluster head and the base station, and d_{toCH} is the average distance between the cluster members and the cluster head.

2.5 Communication Patterns

In WSNs the three types of communication is available viz are ;

- Member node to CH
- CH to CH
- CH to sink

The first one is called intra-cluster communication. In this type the member node sends sensed data to CH or cluster head sends a beacon, query message to its members. The second one is called as inter-cluster communication. CHs sends their aggregated data to sink via intermediate CHs with multi-hop communication. In the last type the CHs sends aggregated data directly to the sink.

2.5.1 Beaconing

The Sensor nodes uses the beacons in order to maintain neighborhood and maintain the routing tables. This beaconing allows the nodes to notice whether the neighbor node is alive or dead, thus network rapidly diagnose and solve the problems about node deaths. The IEEE 802.15.4 standard defines super frame structure controlled by the PAN coordinator to synchronize the nodes in the PAN. On the other hand, PAN coordinator may create contention free period (CFP) and allocate intervals for devices in order to provide guaranteed time slots (GTSs) for devices. This CFP is suitable for applications for low latency that requires specific bandwidth. These super frames are bounded by two beacons sent by the PAN coordinator. Any device in the PAN which wants to send data during the contention access period (CAP) between two beacons competes with other devices using a slotted CSMA-CA mechanism.

2.5.2 Data Aggregation Method

WSNs have large number of sensor nodes to form a network, thus there can be a lot of neighbor node in a small area. This leads to sensing same phenomena by many neighbor nodes. Data aggregation is performed by coordinators such as cluster heads. There are several kinds of data aggregation method such as clustering-based approach, tree-based approach, centralized approach, In-network aggregation etc. In cluster-based approach, nodes send their sensor data to CH, and then CH aggregates data and sends to remote sink. In centralized approach, each node sends data remote leader node via shortest path with using multi-hop communication, then the leader node aggregates sensor data.In addition to combine data from different neighbors into a single packet, this method combines data with applying compression.Summarization of data in such conditions is a requirement in order to reduce communication load of the network. In-network aggregation method executes aggregation by intermediate nodes of the multi-hop network for reducing resource consumption. Tree based approach forms an aggregation tree and all leaf nodes send data to parent node, then parent nodes send aggregated data to sink.

2.5.3 Clustering in WSNs

The Grouping sensor nodes into the clusters has been widely used in the WSNs in order to obtain objectives such as, load balancing, maintaining connectivityscalability, energy efficiency etc. In MANETs clustering method is used to generate stable clusters in environments with mobile nodes to maintain node reachability and route stability. On the other hand, clustering methods on WSNs focus on network longevity and coverage as in shown in Figure 3.Sensor network is separated into groups called clusters and every cluster has a coordinator node called cluster head.

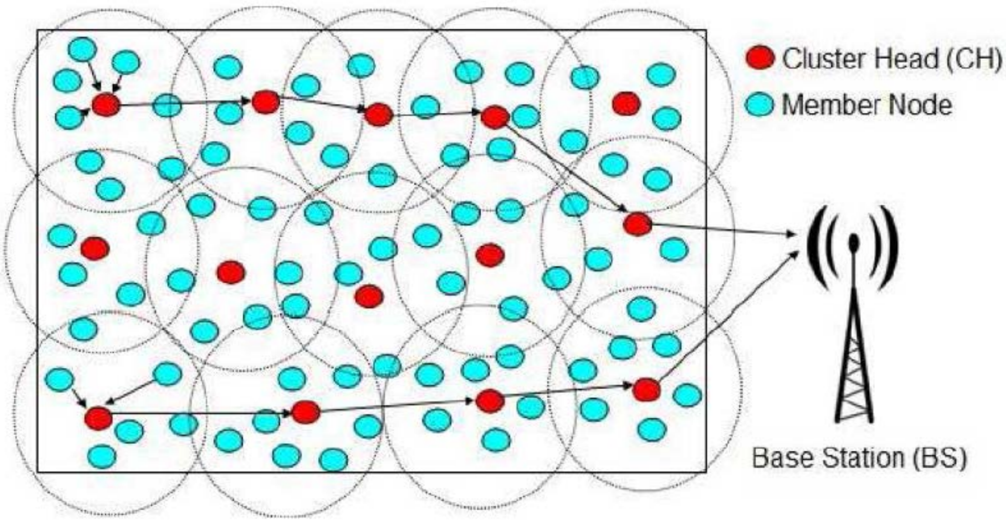

Figure 2.3 Cluster topology

In a clustered WSN, the intra-cluster communication is executed between the cluster members and CH either in a single or multi-hop manner. Inter-cluster communication is performed among CHs or CH to sink. In this part of the thesis we examined and categorized clustering algorithms proposed in the literature for WSNs that have consider energy efficiency**.**As shown in Figure 3 cluster heads have high energy load due to inter-cluster communication. On the other hand member nodes consume low power for intra-cluster.

The ongoing research on multipath routing tries to cope up with fault tolerance and resource limitations of the low power sensor nodes through concurrent data forwarding over multiple paths. This section introduces some of the recent research in this area.

In energy constrained sensor networks of large size, it is very difficult for the sensors to transfer data directly to the sink. In these situations the sensors can transmit the information to local aggregator or cluster and then to sink [1]. So in this network, the sensor nodes are organized in the form of clusters. Here sensors transmit the information to cluster head and there by this cluster head aggregates all the data received from sensors and then transmits the concise data to sink. The cluster head can communicate with the sink either through long range transmissions or multi hoping via other cluster heads. Thus this process results in saving the energy and mainly useful for energy-constrained sensors. Various cluster based protocols have been proposed by numerous researchers such as LEACH (Low-Energy Adaptive Clustering Hierarchy), TEEN (Threshold Sensitive Energy Efficient Sensor Network), SEP(Stable Election Protocol) etc.

2.5.4 Advantages of clustering based routing protocol

Routing in WSN consist various challenging issues such as power supply, scalability, processing capability, transmission bandwidth, global address, frequent topology changes, data aggregation, data redundancy, etc.

Clustering routing protocols try to overcome few of these challenges some of them are listed below:

- Load Balancing: Load balancing can be done by even distribution of nodes in the cluster and the data fusion at the cluster head before inter-cluster transmission. CH is responsible for load balancing within the cluster.

- Fault Tolerance: In WSN nodes are deployed in harsh environment and thus nodes are usually exposed to risk of malfunction and damage. Tolerating the failure of nodes or CH is necessary in such conditions. Whenever a CH fails re-electing of CH will not be efficient rather than we can assign a backup CH. Rotating the role of CH among the nodes in the cluster is also a solution for CH failure.

- Data Processing: Data redundancy can be reduced by aggregating the packets send by various nodes in the cluster to the CH. Thus various redundant data can be removed during this process.

- Energy Efficient: Data aggregation at CH reduces data transmission and thus saves energy. Whereas inter-cluster communication helps in less energy consumption.

- Robust: WSN like wired network doesn't have any fixed topology thus addition of new node, node mobility, node failure, etc. has to be maintained by the individual cluster not by the entire network. CHs rotate among the entire sensors node to avoid single point of failure.

- Network Lifetime: Clustering routing protocol helps in energy-efficient routing thus the overall network lifetime is increased.

2.6 Classifications For Routing Protocols For Wireless Sensor Network

In cluster based or hierarchical protocols nodes are grouped into clusters. Every cluster has a cluster head the election of which is based on different election algorithms. The cluster heads are used for higher level communication, reducing the traffic overhead. Clustering may be extended to more than just two levels having the same concepts of communication in every level. The use of routing hierarchy has a lot of advantages. It reduces the size of routing tables providing better scalability. To attain better performance the concept of hierarchical routing is utilized to perform energy-efficient routing in wireless sensor network. A variety of protocols have been discussed for prolonging the life of WSNs and routing the correct data to the base station. Some of the energy aware routing protocols are:- Low energy Adaptive Cluster Hierarchy routing protocol (LEACH), Power efficient gathering in sensor information system (PEGASIS), Threshold sensitive energy efficient sensor network protocol (TEEN), Hierarchical power aware routing, Virtual Grid Architecture, Base station controlled dynamic clustering protocol

2.6.1LEACH protocol:

Heinzelman, et al. [7] introduced one of the most popular hierarchical cluster-based routing protocols which include distributed cluster formation called Low Energy Adaptive Clustering Hierarchy (LEACH) as shown in figure 4. The main idea is to form clusters of the sensor nodes based on the received signal strength and use a local cluster head (routers) to the sink. Energy is saved from this protocol since transmission will only be done by cluster heads rather than the all sensor nodes. LEACH uses a TDMA/code-division multiple access (CDMA) MAC to reduce inter-cluster and intra-cluster collisions.

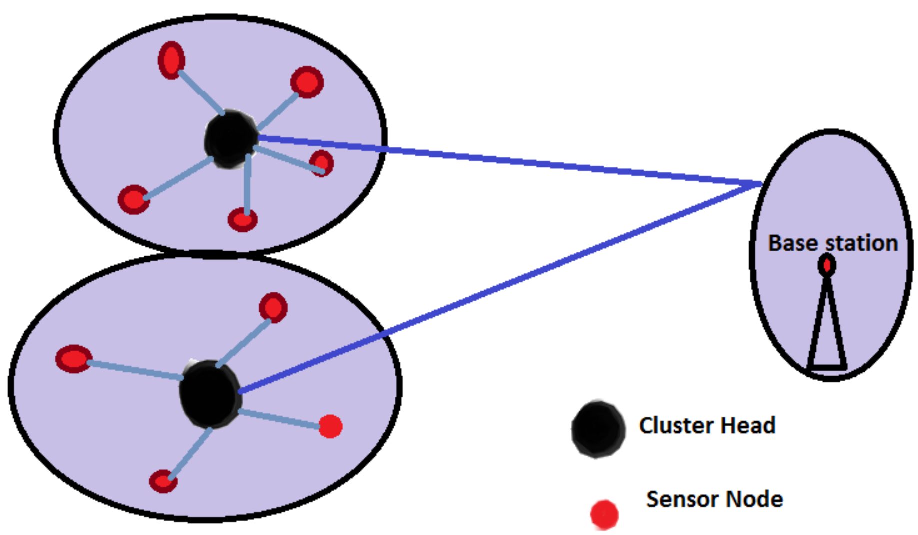

Figure 2.4: LEACH Protocol

The operation of the LEACH protocol separated into two phases

- The Setup Phase: Clusters are organized and the cluster heads are selected. Cluster heads (CH) change randomly over time in order to balance the energy dissipation of nodes. Cluster head [10] accumulates, compress and forward the data to the base station. This decision is made by the node choosing a random number between 0 and 1.If random number is less than a threshold value, T (n) for the current round the node will become cluster head.
- The Steady state phase: Sensor nodes start sensing and transmitting data to the cluster heads. After receiving all the data the CH node [9] aggregates it before sending it to the base station. In order to minimize overhead, the duration of the steady state phase is longer than the duration of the setup phase. Moreover, each node that is not a cluster head selects the closest cluster head and joins that cluster. After that the cluster head creates a schedule for each node in its cluster to transmit its data.

Advantages:

As Hierarchical Topology, LEACH is fundamental algorithm design.

Better energy utilization and system life time.

The algorithm provides prolonged network coverage (low latency).

Disadvantages:

Fault-tolerance issues – when nodes fail or behave unexpectedly.

2.6.2. PEGASIS (Power-Efficient Gathering in Sensor Information Systems):

PEGASIS [8] is nearly optimal chain-based protocol and enhancement over the LEACH protocol as given in figure 5 Instead of forming multiple clusters it forms chain from sensor nodes so that each node can transmit and receives from neighbor. One node is selected from the chain to transmit the data to the base station Moreover; all the sensor has a global knowledge about the network mainly position of sensors are concerned by using a greedy approach.

Steps in PEGASIS Protocol:

1. Chain construction: To construct the chain we start from the furthest node from the base station and then greedy approach is used to construct the chain.
2. Step two in PEGASIS Protocol:
   - Leader of each round is selected randomly from the chain and transmits the gathered data to the base station.
   - When a node dies chain is reconstructed to bypass the dead node.
   - Head node receives all the fused data and sends to the BS.

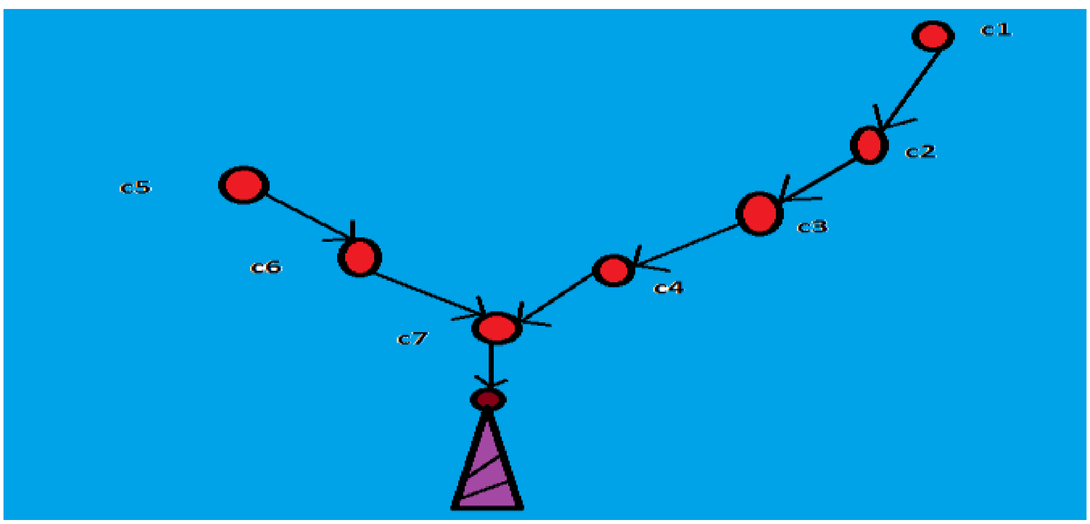

Figure 2.5: PEGASIS Protocol

Advantage:

There is no examination of base station`s

Disadvantages of the PEGASIS protocol:

- When a head node is selected, there is consideration how far the BS is located from the head node.
- There is only one node head; it may be the bottle neck of the network causing delay
- Redundant transmission of data as only one head node is selected.

2.6.3.TEEN (Threshold-Sensitive Energy Efficient Protocols):

This protocol mainly proposed for the conditions like sudden changes in the sensed attributes such as temperature [9]. The network is operated in a reactive mode in where responsiveness is important for time-critical applications. CH sends two types of data to its neighbors—one is the hard threshold (HT) and other is soft threshold (ST).

Hard Threshold (HT): This threshold value is used for the sensing the attribute. It is absolute value of the attribute beyond which, the node sensing this value must switch on its transmitter and report to its cluster head. Moreover, hard threshold tries to reduce the number of transmissions by allowing the nodes to transmit only when the sensed attribute are in the range of interest.

Soft Threshold (ST): Small change in the value of the sensed attribute that triggers the node to switch on its transmitter and transmit the data. It reduces the number of transmissions by eliminating all the transmissions which might have occurred when there is little or no change in the sensed attribute once the hard threshold.

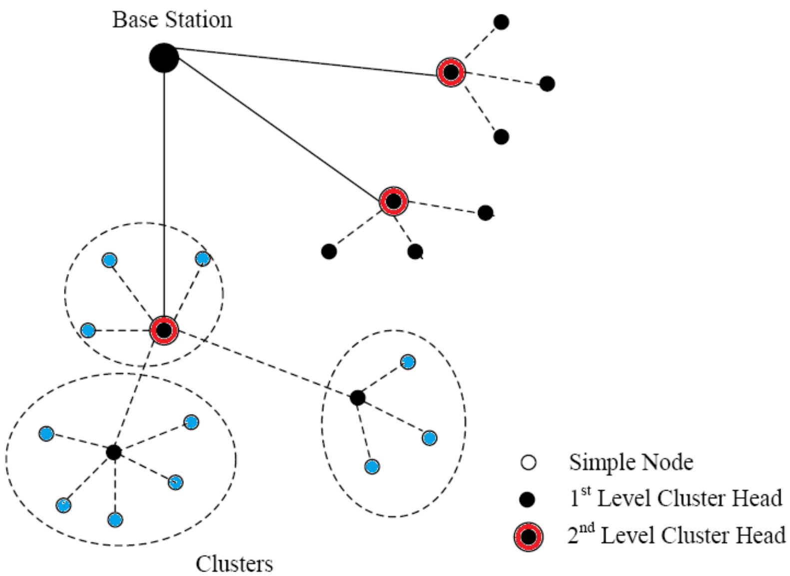

Figure 2.6 : TEEN Protocol

2.6.4 DEEC (Distributed Energy Efficient Cluster Formation Protocol)

DEEC is designed for Multi-level heterogeneous environment. The criteria for selecting cluster head in DEEC depends upon a probability which is based on ratio between residual energy of every node and average energy of the whole network. So nodes with high initial and residual energy have more chances to become CH than nodes with low energy. Thus DEEC can prolong the stability period by heterogeneous aware clustering algorithm. The total initial energy of two level heterogeneous network is given as:

$$E_{total} = N(1-m)E_o + NmE_o(1+a) \qquad (2.5)$$

Where E_o is initial energy of the network, m is fraction of advance node which has a times more energy than normal node, mN is advance node having initial energy (1-m)E_o and (1-m)N is normal node having initial energy E_o .

2.6.5 HEED- Hybrid Energy-Efficient Distributed Protocol:

HEED[16] proposes a novel distributed clustering approach for long-lived ad hoc sensor networks. The proposed approach does not make any assumptions about the presence of infrastructure or about node capabilities, other than the availability of multiple power levels in sensor nodes. The protocol is a novel clustering based protocol that periodically selects cluster heads according to a hybrid of the node residual energy and a secondary parameter, such as node proximity to its neighbors or node degree. The authors have shown that the HEED protocol a significant increase in network scalability and lifetime. In [17], a hybrid HEED protocol which can be assumed to be extension of the HEED, the feasibility of the HEED protocol for a heterogeneous network is studied and a novel algorithm which includes the node heterogeneity in terms of node energy is proposed.

2.6.6 DEEC- Distributed Energy Efficient Protocol

DEEC[18] DEEC is designed to deal with nodes of heterogeneous WSNs. For CH selection, DEEC uses initial and residual energy level of nodes. Let ni denote the number of rounds to be a CH for node s_i. p_{opt}N is the optimum number of CHs in our network during each round. CH selection criteria in DEEC is based on energy level of nodes. As in homogenous network, when nodes have same amount of energy during each epoch then choosing pi = p_{opt} assures that p_{opt}N CHs during each round. In WSNs, nodes with high energy are more probable to become CH than nodes with low energy but the net value of CHs during each round is equal to poptN. pi is the probability for each node si to become CH, so, node with high energy has larger value of pi as compared to the popt. E(r) denotes average energy of network during round r which can be given as below:

$$E(r) = \frac{1}{N}\sum_{i=1}^{N} Ei(r) \quad (2.6)$$

2.7 Summary

The WSN is one of the most important technologies for the present century. It is composedof a large number of the sensor nodes. These sensor nodes may operate autonomously togather process and communicate data about a specified environment. These arealso small in size, low-cost, low power and have multi-functional properties. WSN is suffered from various challenges due to the node mobility, power source, range from the target region, etc. In spite of these challenges the application area for WSN is very large.These arealso constrained in limited power source, ability to withstand in the harsh environmentalconditions, mobility of nodes, dynamic network topology, and unattended operations.

CHAPTER 3
METHODOLOGY

Many research projects in the last few years have explored hierarchical clustering in WSN from different perspectives. Clustering is an energy-efficient communication protocol that can be used by the sensors to report their sensed data to the sink**.** Hierarchical approach breaks the network into clustered layers. Nodes are grouped into clusters with a cluster head that has the responsibility of routing from the cluster to the other cluster heads or base stations. Data travel from a lower clustered layer to a higher one. Although, it hops from one node to another, but as it hops from one layer to another it covers larger distances. This moves the data faster to the base station. Clustering provides inherent optimization capabilities at the cluster heads. In this section, we review a sample of hierarchical-based routing protocols for WSNs.

3.1 Network life time

It is the amount of time that a Wireless Sensor Network would be fully operative. One of the most used definitions of network lifetime is the time at which the first network node runs out of energy to send a packet, because to lose a node could mean that the network could lose some functionality. But, is also possible to use a different definition, in which some nodes could die or run out of battery power, whenever other network nodes could be used to capture desired information or to route information messages to their destination.Most of sensor nodes in a WSN forward their data to the BS by using long multi-hopping paths. Therefore the intermediate nodes in a long multi-hop path have to send their own data to sink as well as forward data from other nodes to sink. These nodes depleted energy more quickly than nodes near the boundary. The situation is worse in case of the sensor nodes which are deployed near the sink [3]. These nodes have to relay sensed data from the entire network to the sink. As these sensor nodes also contain a limited energy source, therefore due to frequent data transmission through these nodes, these nodes die soon. In such situation, the other alive nodes in the network cannot send their data to the sink. The entire WSN becomes non-functional. Wireless sensornetworks should active as long as possible system lifetime can be Measured using application specific parameters such as the time until the sensor network is providing acceptable quality results or it can be measured using generic parameters such as the time until the nodes die.

3.2 Solution Methodology

In order to save the total energy cost of the sensor networks and prolong its lifetime, a threshold based distributed energy protocol has been proposed. The basic idea of the protocol is as follows:

Firstly some assumptions are addressed in our work:

- All nodes can send data to Base station (BS).
- The BS has the information about the location of each node. It’s assumed that the cluster heads and nodes have the knowledge of its location.
- In the first round, each node has a probability ‘p’ of becoming the cluster head.
- All nodes are of same specification.
- All nodes in the network are having the same energy at starting point and having maximum energy.
- Energy of transmission depends on the distance (source to destination) and data size.
- Nodes are uniformly distributed in network in a random manner.

The research work done here has mainly focussed on realistic situational aspect of the Wireless Sensor Networks. With the kind of application for which the wireless sensor nodes are employed its important for them to have situational awareness which is directly linked to their energy consumption. If we can keep an eye on the situation and acoordingly monitor and control the energy being used in the Wireless Sensor Networks,hence improving the efficiency of the network. Following the thoughts of LEACH, DEEC lets each node expend energy uniformly by rotating the cluster-head role among all nodes. cluster-heads are elected by a probability based on the ratio between the residual energy of each node and the average energy of the network. The round number of the rotating epoch for each node is different according to its initial and residual energy, i.e., DEEC adapt the rotating epoch of each node to its energy. The nodes with high initial and residual energy will have more chances to be the cluster-heads than the low-energy nodes.The proposed protocol here also monitors the behaviour of the nodes and Cluster Heads with respect to energy and distance. In this proposed algorithm, once the potential of each node is calculated, the head of cluster head (CH) or the leader node is selected on the basis of the energy level of the various nodes. The distance of all nodes from the base station or sink is then evaluated to locate the nearest and farthest nodes in the network. Based on a threshold distance level a temporary leader node is selected for each cluster. The energy and distance from the base station is then evaluated and the ratio between them is evaluated. If this ratio is above the threshold value then the cluster head is the optimal selection for this round for that cluster. The process is continued further by continuous monitoring of the values of energy of nodes and the distance from the base station.

$$\text{Selection Potential (Q)} = \frac{E}{DtoBS} \qquad (3.1)$$

The selection of child nodes i.e. the nodes that can potentially be cluster heads in the upcoming rounds is done subsequently using the same metrics i.e. the distance to base station and the energy of the nodes. Apart from this the distance between the all nodes under a particular cluster and cluster head is also evaluated and compared to a threshold value according to the round number. The nodes which do not satisfy the distance parameters i.e. who have the distance value less than the threshold for the current round from the cluster head it is assigned a new cluster. Thus ensuring the connectivity of all nodes in the network at a particular instant of time.

Cluster Setup Base:

As is the case with most cluster based techniques, the algorithm starts with the formation of clusters i.e. cluster setup phase. Initially, when clusters are being created, each node decides whether or not to become a cluster-head for the current round. This decision is based on the suggested percentage of cluster heads for the network (determined a priori) and the number of times the node has been a cluster-head so far. This decision is made by the node n choosing a random number between 0 and 1. If the number is less than a threshold T(n), the node becomes a cluster-head for the current round. The probability of selection is is given as:

$$p(i) = \begin{cases} \frac{P}{1-P*(r \bmod \frac{1}{P})} & If\ n \epsilon G \\ 0 \quad Otherwise \end{cases} \qquad (3.2)$$

Where P = the desired percentage of cluster heads (e.g., P = 0.05), *r* = the current round, and G is the set of nodes that have not been cluster-heads in the last *1/P* rounds. Using this threshold, each node will be a cluster-head at some point within *1/P* rounds. During round 0 (*r* = 0), each node has a probability *P* of becoming a cluster-head. The nodes that are cluster-heads in round 0 cannot be cluster-heads for the next *1/P* rounds. Thus the probability that the remaining nodes are cluster-heads must be increased, since there are fewer nodes that are eligible to become cluster-heads.

After *1/P* -1 rounds, T=1 for any nodes that have not yet been cluster-heads, and after *1/P* rounds, all nodes are once again eligible to become cluster-heads. Future versions of this work will include an energy-based threshold to account for non-uniform energy nodes. In this case, we are assuming that all nodes begin with the same amount of energy and being a cluster-head removes approximately the same amount of energy for each node. Each node that has elected itself a cluster-head for the current round broadcasts an advertisement message to the rest of the nodes. For this "cluster-head-advertisement" phase, the cluster-heads use a CSMA MAC protocol, and all cluster-heads transmit their advertisement using the same transmit energy. The non-cluster-head nodes must keep their receivers on during this phase of set-up to hear the advertisements of all the cluster-head nodes.

The DEEC protocol is based on a two-level heterogeneous WSN in which the sensor nodes are assumed to have normal and advanced battery levels. The above formula for selection probability for the two types of nodes is thus given by:

$$p(i) = \begin{cases} \frac{\text{Ei (r)popt} * \text{a}}{(1+a)Eavg} \quad if\ normal \\ \frac{\text{Ei (r)popt}}{(1+a)Eavg} \quad if\ advanced \end{cases} \tag{3.3}$$

Distance Factor:

Apart from the conventional energy threshold criterion being used in most of the LEACH based techniques; this research work also incorporates the distance threshold for deciding the selection of cluster heads in the subsequent rounds. The two key matrices i.e. the Distance of the nodes from the base station as well as the distance of nodes in a cluster from the current cluster head is also evaluated and is used as the basis for selection of upcoming cluster head. Thus, this technique uses a combination of both energy and distance awareness of the nodes. This can be critical information because not only we can keep track of the nodes position but also provide complete coverage for all nodes, thus leading to energy efficiency. As mentioned in equation 4.1 the Selection Potential is a ratio between, energy and distance of nodes from base station. After this phase is complete, each non-cluster-head node decides the cluster to which it will belong for this round. This decision is based on the received signal strength of the advertisement.

$$d = \sqrt{(\mathrm{s(i).xd} - \mathrm{s(n+1).sink\,x})\wedge^{2} + (\mathrm{s(i).yd} - \mathrm{s(n+1).sink\,y})\wedge 2} \qquad (3.4)$$

Radio Model:

In our work, we assume a simple model where the radio dissipates E_{elec} = 50 nJ/bit to run the transmitter or receiver circuitry and E_{amp} = 100 pJ/bit/m2 for the transmit amplifier to achieve an acceptable E_b*/No*. These parameters are slightly better than the current state of the art in radio design1. We also assume an r2 energy loss due to channel transmission. Thus, to transmit a k-bit message a distance d using our radio model, the radio expends:

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d)$$

$$E_{Tx}(k,d) = E_{elec} * k + \epsilon_{amp} * k * d^2 \qquad (3.5)$$

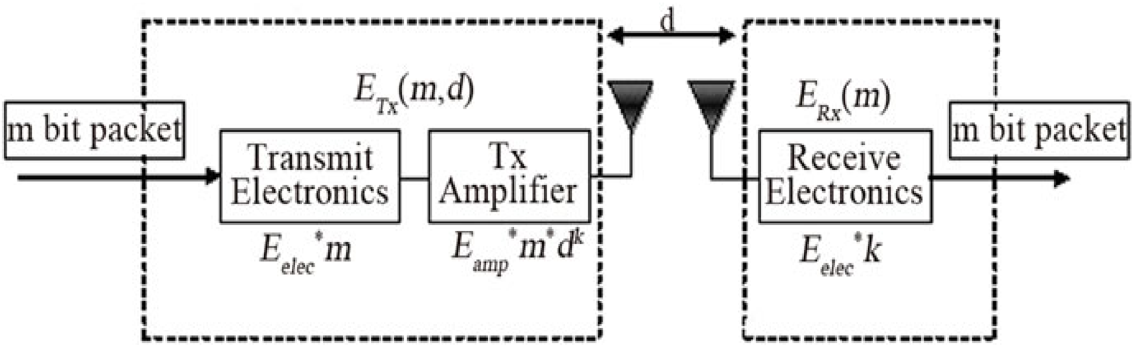

Fig 3.1 Radio Model

And to receive this message, the radio expends:

$$E_{Rx}(k) = E_{Rx-elec}(k)$$

$$E_{Rx} = E_{elec} * k \qquad (3.6)$$

Proposed Work:

The proposed algorithm uses the same uses same mechanism for CH selection and average energy estimation as proposed in DEEC. At each round, nodes decide whether to become a CH or not by choosing a random number between 0 and 1. If number is less than threshold Ts as shown in equation below then nodes decide to become a CH for the given round.The threshold value T(s) is adjusted and based upon that value a node decides whether to become a CH or not by introducing residual energy and average energy of that round with respect to optimum number of CHs.

$$T(s) = \begin{cases} \frac{P}{1-P*(r \bmod \frac{1}{P})} * \frac{residual\ \ energy\ \ of\ a\ node\ *kopt}{average\ \ energy\ \ of\ the\ network} \end{cases} \quad (3.7)$$

Theaverage probability to be a cluster-head during ni rounds. When nodes have the same amount of energy at each epoch, choosing the average probability pi to be popt can ensure that there are poptN cluster-heads every round and all nodes die approximately at the same time.

According to the threshold equation, the cluster head selection is optimized.

If nodes have different amounts of energy, pi of the nodes with more energy should be larger than popt.

Let E(r) denote the average energy at round r of the network. To compute average energy each node should have the knowledge of the total energy of all nodes in the network to be the reference energy, we have the following equation:

$$E(r) = \frac{1}{N}\sum_{i=1}^{N} Ei(r) \quad (3.8)$$

The probability of the ith node selection can then be given by:

$$p_i = p_{opt}\ E_i\ (r)/\bar{E}_i\ (r) \quad (3.9)$$

CHAPTER 4

SIMULATION ANALYSIS AND RESULT

4.1 Introduction

We present and discuss the obtained results of the proposed simulated protocol and comparison with running another technology. The analysis of the proposed work has been done using the MATLAB simulation and programing environment. MATLAB R2013 a has been used for simulating the virtual Wireless Sensor Network environment. The following manuscript gives a brief description of the MATLAB software and then shows the various results and findings of this research work.

4.2 Simulator Overview

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. [28, 29].

4.3 Results and Analysis

To evaluate the performance of our protocol, implemented it has been implemnted in MATLAB platform,. Our goals in conducting the simulation are as follows:

Create the environment of wireless sensor network. performed on a network of 100 nodes and a fixed base station. The nodes are placed randomly in the network. Cluster formation is done as in the DEEC protocol.

4.3.1 Simulation parameters:

4.1 Table Of Used Parameter

Parameter	**Value**
Number of sensor nodes	100
Network size (m^2)	100*100 m^2
No of round	5000
Base station location	(50,50)
Efs (pJ/bit)	10*10^(-12)
Eamp (pJ/bit)	0.0013*10^(-12)
ETX (nJ/bit)	50*10^(-9)
ERX (nJ/bit)	50*10^(-9)

Table 4.1 shows the network simulation parameters required to define the various characterstics related to the sensor nodes

4.3.2 Simulated Environment

- The sensor network nodes are first placed randomly in a bounding area of 100x100 units.

Base station situated out of the network. Different colours are showing the different sensor nodes

- We use three metrics to analyze and compare the performance of the protocols. They are number of dead nodes in each round, the number of alive nodes in each round and the number of packets transferred in each round.

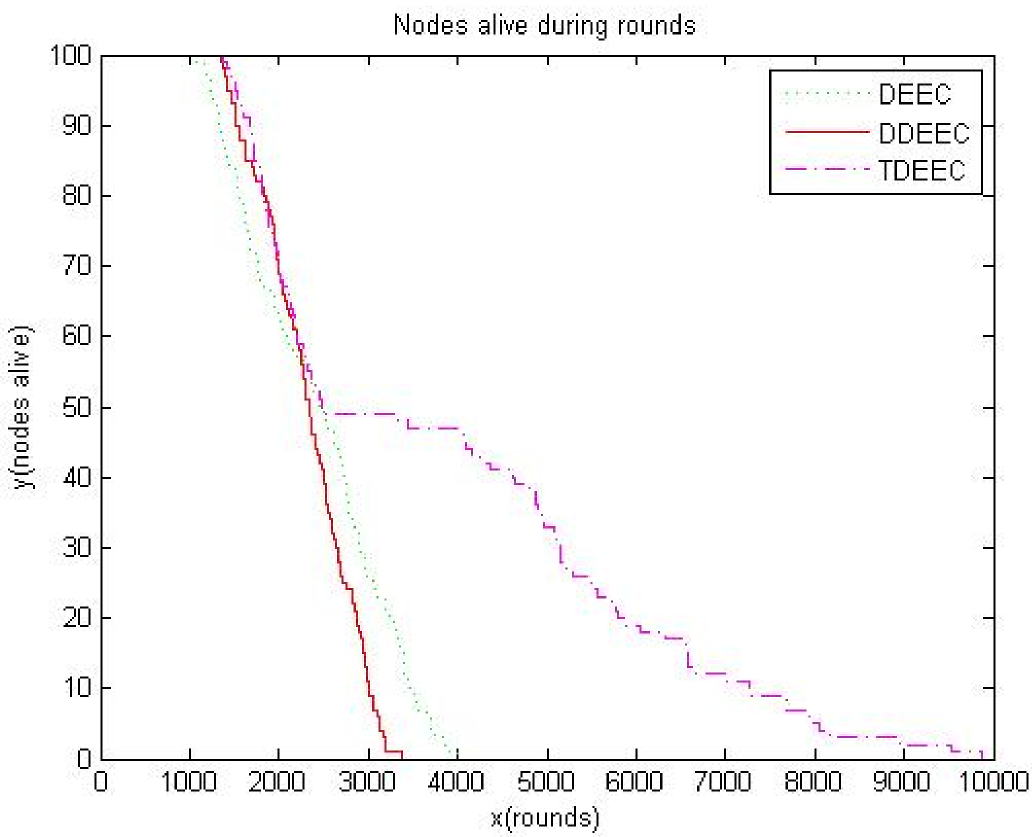

Figure 4.2: Number of Alive Nodes

In our simulation, the age of the network or in other words the network lifetime is indicated by the number of nodes alive after a certain number of rounds. The figure 4.2 shows the curve for the number of alive nodes while the figure 4.3 gives the number of dead nodes. As is seen from both the graphs, there is a drastic change(fall in the number of alive nodes and rise in the number of dead nodes), in the curve.

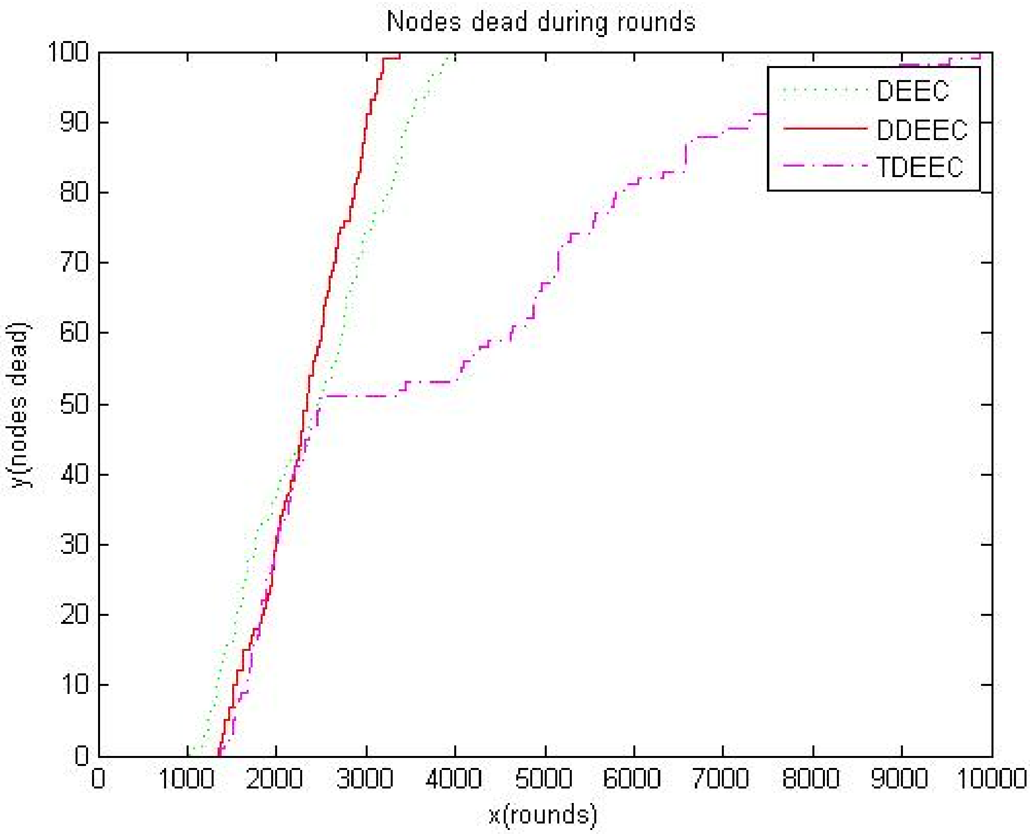

Figure 4.3: Number of Dead Nodes

The number of alive nodes has fallen sharply from around 90 to approximately nodes in figure 4.2. and, similarly there has been a steep rise in the number of dead nodes in figure 4.3. This drastic change has occurred at around halftime of the total network time i.e around after 2000 rounds and can be attributed to the considerable loss of the energy at the network half time.

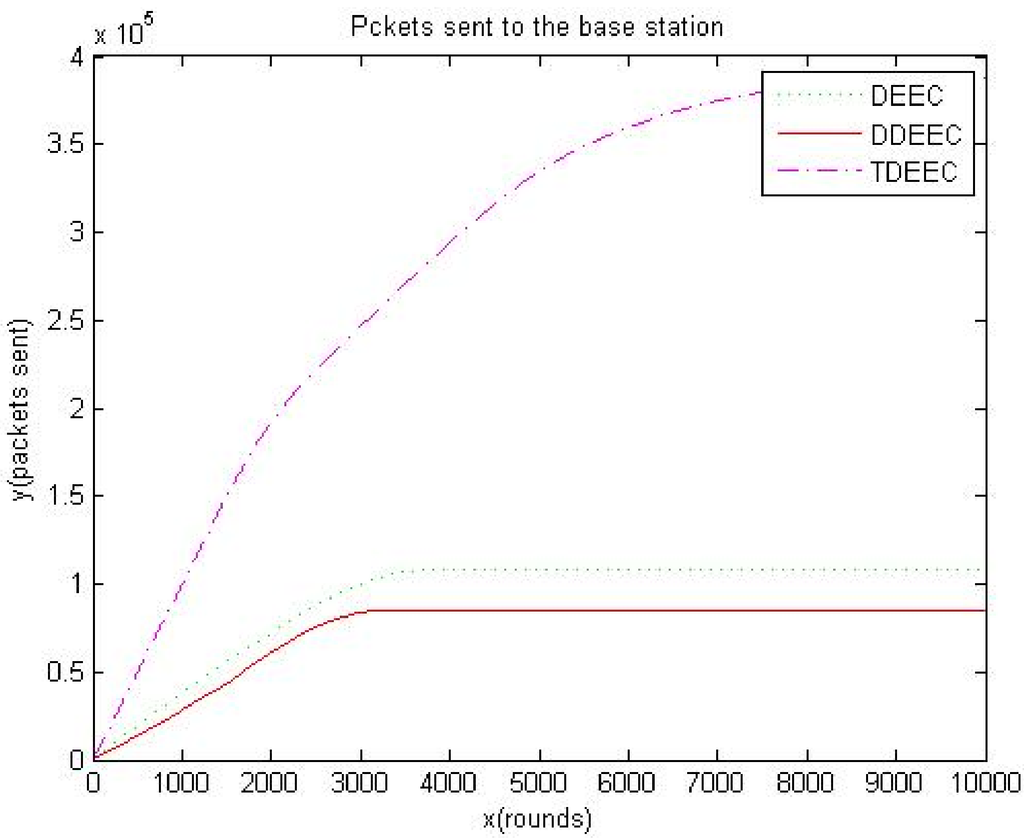

Figure 4.4: Number of Packets transferred to Base Station

Figure 4.4 shows the graph between DEEC, DDEEC and proposed method for the number of packets transferred from Cluster heads to the base station.

Chapter 5

Conlusion and Future Work

5.1 Conclusion

The Wireless Sensor networks has been rapidly used in various applications throughout, especially in areas which require continous monitoring and survilleance. This requires for the sensor nodes to be always active to sense every particular information at every instant of time. This particular requirement however, takes a heavy toll of the power(which is mostly battery powered). Thus, saving energy and battery power so as to prolong the lifetime of the whole network is an important area of reaserch when designing any reliable network setup for such kind of an environment.

In this research work, the energy model of a Wireless Sensor Network was thorooughly studied along with the various protocols which are being used or proposed earstwhile. An important task assigned to the sensor nodes is to relay the information sensed by them to the base station which is a central control center of the entire network. The communication between the sensor nodes and the base station is done through a set of methods which are known as protocols. In this resaerch work a numbe rof clustering protocols were studdied and their key features were noted. The heterogenous DEEC protocol was modified where a node becomes a cluster head only if it posseses acertain threshold value is taken as areference and a modified method which takes into account the distance factor as well has been studied and simulated.

In the network setup, part from the conventional energy threshold criterion being used in most of the LEACH based techniques; this research work also incorporates the optimal threshold for deciding the selection of cluster heads in the subsequent rounds. The awareness of the distance and average energy of the network helps to understand the network more effectively. Especially, in the case of multi path communication it helps to save the energy wastage. The selection potential i.e. the capability to become the cluster head in a particular round has been evaluated from this distance metric. Thus the method improves the performance as is being shown by different curves like residual energy, number of alive nodes etc. which are a metric for knowing the network lifetime. The method shown has been compared with and DDEEC and DEEC to show it effectiveness.

5.2 Future Work

As mentioned in the above section, the awareness about the network and the position of the nodes can save a lot of energy as well as provide coverage to all the nodes, till the last node is alive. This research work has been constrained to a homogenous network structure with a particular set of network parameters, The work can be extended further to different network environments especially to the heterogeneous environments. Another research paradigm can be to use the concept of selection potential to some other popular clustering protocols. The idea presented in this research can be helpful in guiding future research work in this field.

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2) Maneesh Kumar Mishra and Ashawani Kumar ,”A Review of Wireless Sensor Networks ,”International Journal for Research in Applied Science and Engineering Technology (IJRASET) ISSN 2321-9653 Volume 7, Issue IV ,April 2019.

CURRICULUM VITAE

MANEESH KUMAR MISHRA
M.Tech (WIRELESS COMMUNICATION & SENSOR NETWORKS)
Email: maneesh9452@gmail.com

Educational Summary:

Qualification	Istitution	Year of Passing	University/Board	Percentage/Grade
Pursuing M.tech (WIRELESSCOMM.&SENSOR NETWORK)	Babu Banarasi Das University	2018	BBDU	
B.Tech(Electronics& Commu. Engineering)	FGIET RAEBARELI	2014	UPTU	68%
INTERMEDIATE	K I C BABHNAN	2006	UP BOARD	65%
HIGHSCHOOL	K I C BABHNAN	2004	UP BOARD	57%

Training:

BHARAT SANCHAR NIGAM LIMITED

Final Year Project (B.Tech):

LINE FOLLOWING ROBOT

Personal detail:

Father's Name: Late R.C.Mishra

Mother's Name: Umesh Mishra

Date of Birth : 15/JUL/1991

Natioanlity : Indian

Sex: Male

Language Proficiency: English ,Hindi

Present Address : Ward 10 mahagauri Nagar BABHNAN BASTI